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ABSTRACT

During the fall of 2000, first and second year engineering students were observed throughout the semester as they interacted in engineering design teams. Eighty women and 258 men signed the consent form to participate in the study. The observational protocol that was used was based on L. Eberhardt's 10 categories of team functions, which are evenly divided between process and task functions. The results of the investigation suggest that the functions that males and females display change during the team process. In addition, the gender composition of the team appears to impact the functions that are exhibited by individual team members. (Contains 3 tables and 23 references.) (Author/SLD)

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Engineering Design:

Functions of Males and Females Throughout the Team Process

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Abstract

During the fall of 2000, first and second year engineering students were observed throughout the semester as they interacted in engineering design teams. The observational protocol that was used was based on Eberhardt's ten categories of team functions, which are evenly divided between process and task functions. The results of the current investigation suggest that the functions that males and females display change during the team process. Additionally, the gender composition of the team appears to impact the functions that are exhibited by individual team members.

Theoretical Background

Curriculum reform in engineering education is currently underway that stresses the importance of teamwork, an awareness of both society's social and economic concerns, and an ability to adapt to the changing demands of the work environment (Dixon 1991; Masi 1995; Maul 1994). Many engineering schools have adapted their curriculums to include engineering design courses that focus upon the development of these important skills and that include industrial partners in the curriculum design effort (Al-Holou, Bilgutay, Corletor, Demel, Fleder, Frair, Froyd, Hoit, Morgan & Wells, 1999; King, Parker, Grover, Gosink & Middleton, 1999; Sheppard & Jeninson 1997). Engineering design is a creative, interactive, and complex decision-making process. The team solution evolves over an extended period of time and is a direct result of the team's ability to synthesize information, skills, and values. This process requires inputs from many perspectives—material, analytical, historical, aesthetic, ethical, structural, and creative (Knecht, Moskal & Pavelich, 2000; Moskal, Knecht & Pavelich, 2001).

Eberhardt (1987) has identified two sets of functions that are necessary to operate optimally as a team. Her instrument consists of ten categories and these are evenly divided between task and process functions. Task functions, critical to product quality, focus on implementing tasks aimed at the overall team goal. Process functions, critical to team satisfaction, help teams to operate efficiently and effectively. It is the synthesis of these functions that leads to successful problem solving, organizing and marketing. Eberhardt's instrument is based on the research of Benne and Sheats (1948). Since 1948, researchers have repeatedly recognized these functions as critical aspects of the team process (e.g., Fisher, 1970; Jones, 1999).

Simultaneous to the curriculum reform efforts that are underway in engineering education, there is also an on-going effort to encourage more women to pursue engineering degrees (Blaisdell & Anderson-Rowland, 1997; More, Blaisdell, & Anderson-Rowland, 2000; Moskal, Lasich & Middleton, 2001; White, Blaisdell & Anderson-Rowland, 1999). If successful, these efforts will result in a gradual shift in the population of engineering schools from their current male dominated student body to a more even distribution of genders. Prior research has suggested that during team interactions female contributions tend

to be process oriented and male contributions tend to be task oriented (Helgesen, 1990; Wylie, 1996). This research, however, has primarily focused upon males and females in executive positions. Recent research suggests that these findings may not be generalized to an engineering environment (Moskal, Knecht & Lasich, 2001; MacDonell-Laeser, Moskal, Knecht & Lasich, 2001).

Recognizing the need to better understand the impact that gender has on the engineering design team process, the Colorado School of Mines (CSM) has undertaken a series of research investigations. The first study took place during the summer of 2000 and was funded by the Women's Foundation of Colorado. As part of this investigation, observations were completed during a summer course in the Design Engineering Practices Introductory Course Sequence (EPICS) at CSM. Design EPICS is a sequence of required first and second year courses at CSM in engineering design. As the first course that students take in engineering design, Design EPICS has the potential of either encouraging or discouraging students' (particularly females) interests in engineering. The results of this investigation suggest that male and female leaders in engineering design teams display few behavioral differences during the team process (Moskal, Knecht & Lasich, 2001). Yet, team members' descriptions of the leadership qualities of their male and female leaders were very different. The female leader was described as "being the only female" and therefore, permitted by the males to take the leadership role. The male leader, on the other hand, was described as having long-range goals, organizational skills, computer skills, an ability to get things done, and an ability to take charge. In other words, engineering design team members viewed their male and female leaders very differently.

As a follow-up to this investigation, a more extensive examination of the engineering design team process began in the fall of 2000. This study, *Engineering Design Teams: Influence of Gender Composition on the Decision-Making Process* project (EHR-9979444), was funded by the National Science Foundation's Activities for Women and Girls in Science, Engineering & Mathematics program and used Eberhardt's categories as an observational protocol (1987). Several reports have been produced concerning the results of this investigation.

MacDonell-Laeser, Moskal, Knecht and Lasich (2001) found that there was no overall difference between the average proportion of times that males and females were witnessed displaying Eberhardt's ten functions as they interacted in teams throughout the course of a semester. The gender composition of the overall team did, however, have an impact on the proportion of the time that team members were witnessed displaying a given function. For example, members of male dominated teams were significantly more likely to be witnessed Encouraging other team members to contribute to the team effort than were other team compositions. Male dominated teams were also more likely to set specific standards to guide the team's direction.

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Another report (Moskal, Knecht & Lasich, in press) examined the quality of the final products that all male, male dominated, female dominated and equally mixed teams produced by the end of the semester. The results of this analysis suggest that, based on a standardized scoring system, the all male teams outperformed all other team compositions in the first year of Design EPICS. In the second year of Design EPICS, female dominated teams outperformed all other team compositions.

The current paper is an extension of the work that is described above. As the above results suggest, differences have been identified in the functions and the performance of teams that differ by gender composition. This investigation extends this work by dividing the engineering design team process into three time segments: 1) the first four weeks of the course, 2) the second three weeks of the course and 3) the last four weeks of the course. This paper directly compares the functions that women are witnessed displaying during the team effort to the functions that men are witnessed displaying during the team effort. This investigation also compares the functions that are displayed by individuals in female dominated and mixed gender teams to the functions that are displayed by individuals in male dominated teams. By making these comparisons, a more complete understanding can be acquired of how the team dynamics in engineering design are likely to change as more women enter schools of engineering. The specific research questions that will be addressed are as follows:

1. How do the functions displayed by female engineering design students differ from the functions that are displayed by male engineering design students at various stages during the team process?

2. How do the functions that are displayed by individual engineering design team members in female dominated and mixed gender teams differ from the functions displayed by individual engineering design team members in male dominated teams?

Methods

Courses

The Design EPICS sequence is a two-semester, six credit-hour course sequence that is required of all first- and second-year students. This sequence is designed to provide students with a broad-based introduction to engineering design, technical communications and teamwork. A mentor works with teams of four to six students to solve authentic problems, similar to projects engineers would encounter at the workplace. All projects are authentic in that they are problems that have been solicited from the government, industry and businesses. All of the freshmen students completed the same project, Transporting Lunar Regolith. The purpose of this project was for the team to develop ways to transport

regolith, which is the layer of finely ground dirt on lunar surfaces. The sophomore Design EPICS classes had 14 projects from which to select. Brief descriptions of several example projects are shown in Table 1.

Table 1

Description of Sophomore Year Research Projects at CSM

Title of Project	Description
EPA Indoor Air Quality Extension	Teams identify obstacles and offered suggestions to improve the airflow in large buildings.
Planetary Rover Test Prototype	Teams completed a design study on an existing mechanical vehicle that is suitable to use for planetary regolith excavation and volatile extraction.
Playground Equipment	Teams focused on installing playground equipment that was designed to encourage children with disabilities to interact with their peers.
Ethanol Marketing Study	Teams investigated the market potential for an ethanol product, specifically from cellulosic biomass.
Potato Flower Mold Presentation	The teams designed, developed and constructed a food prototypical mold (something like a cupcake pan) to bake several whipped potato flowers at a time.

Subjects

All appropriate human subject procedures were followed in this study. During the first week of classes, either a researcher or a graduate research assistant attended each class and explained the purpose of the study. The students were asked to provide written consent to participate. All students that were under the age of 18 were also required to have their parent or guardian sign the consent form. This paper is based only on the students from whom consent was acquired.

Eighty women and 258 men signed the consent form to participate in the current study. This represents 79% (80 out of 101) of the females and 75% (258 out of 343) of the males that were enrolled in Design EPICS during the given semester.

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Team Formations

A "team" in this study is composed of two or more students and requires the coordination of all members' efforts to accomplish a goal (Larson & Lafesto, 1989). Teams consisted of four to six members and were constructed in the following formations: 1) all males, 2) more males than females (male dominated), 3) more females than males (female dominated), and 4) half female and half male (mixed). Out of the men who participated in the current study, 75, 154, 13 and 16 were in all male, male dominated, female dominated and mixed teams, respectively. Of the females who participated in the current study, 43, 21 and 16 were in male dominated, female dominated and mixed teams, respectively. One hundred and seventy-eight men were in their first year of Design EPICS; Eighty of the men were in their second year of Design EPICS. Fifty-three of the women were in their first year of Design EPICS; Twenty-seven of the women were in their second year of Design EPICS. Since the primary interest of this study was mixed gender teams, teams in the first formation, all male, were not included in the analysis. How the teams were formed within a given classroom was left to the discretion of the instructor. In other words, in some classrooms the instructor assigned students to a team and in other classrooms the students selected their own team.

Observational Protocol

As was discussed earlier, Eberhardt (1987) identified two sets of functions that are necessary to operate optimally as a team. Her instrument consists of ten categories evenly divided between task and process functions and these are shown in Table 2. Task functions are further broken down into the following: Initiating, Information Seeking, Information Giving, Clarifying and Summarizing. Process functions are further broken down into the following: Harmonizing, Gatekeeping, Encouraging, Compromising and Standard Setting. A definition for each of these categories is provided in Table 2.

The researchers trained two graduate students to use Eberhardt's categories to complete observations during team interactions. Video clips were used to illustrate each of the categories as they occurred during team interactions. Additionally, several of these videos were transcribed and these transcriptions were provided to the graduate students and discussed. The graduate students observed and coded several additional video clips of team interactions. By the conclusion of the training, the students overall agreement was 94.6%.

Table 2

Description of Functions that were Observed

Task Functions	Description
Initiating	Proposing goals or actions, suggesting procedures.
Information Seeking	Asking for clarification or requesting facts pertinent to the discussion.
Information Giving	Offering facts, giving opinions, or answering a question.
Clarifying	Interpreting ideas or suggestions, defining terms, clarifying issues, or clearing up confusion.
Summarizing	Pulling together related ideas, restating suggestions, or offering decisions or conclusions for the team to eliminate confusion.
Process Functions	
Harmonizing	Attempting to reconcile disagreements, or getting people to explore different ideas.
Gatekeeping	Helping to keep communication channels open, facilitating participation, or suggesting procedures that permit sharing remarks with each other.
Encouraging	Being friendly, warm, or responsive. Indicating by body language or remarks acceptance of others' contributions.
Compromising	Offering compromises that yield status when his or her ideas are involved in conflicts, or modifying ideas in the interest of team cohesion or growth.
Standard Setting	Expressing standards for the team to achieve, or applying standards in evaluating quality of team process.

Observations

Throughout the semester, each Design EPICS class had at least one hour a week that was specifically scheduled for the students to work in teams. The graduate students were assigned to observe team interactions during these periods using the observational protocol. Each team was observed for three minutes and the order in which the teams within the classroom were to be observed was randomly

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determined. After the three-minute observation, the graduate students had two minutes to move to the next team for observation. The design of the observations was modeled after that which was successfully used by Javanovic and King (1998).

To assist in recording observations, the graduate students were given a checklist that contained each of the observational categories. At the top of this list was an empty row in which the graduate students recorded the students' names. All of the students had name cards. Each time a given student within a team was observed displaying a given function, the graduate students placed a check under that student's name and next to the appropriate category.

The semester was divided into three time periods: 1) the first four weeks of the semester, 2) the middle three weeks of the semester and 3) the last four weeks of the semester. For each student with respect to each function, a "0" or "1" was coded for each time period and for the total observational period. A "1" indicated that the student was observed displaying the given function at least once during the time period; A "0" indicated the student did not display the function during the given time period.

Results

This section is divided into three subsections. The first section describes the reliability of the coding process. The second analysis uses a logistic regression model to compare female students to male students and determine which gender is more likely to display each of the given functions within the different time intervals. The second analysis uses logistic regression to compare the functions that are displayed by individuals that are members of female dominated and mixed gender teams to that of male dominated teams. All statistical tests were performed at the $\alpha = 0.05$ significance level.

Reliability

In order to ensure the reliability, 67 of the observations were double scored. Table 3 provides the percent of agreement between two raters for each function. As this table suggests, agreement was at an acceptable level for all functions.

Table 3

Percent of Agreement for Reliability Checks for Each Function

Function	Percent
Initiating	79%
Information Seeking	78%
Information Giving	87%
Clarifying	75%
Summarizing	93%
Harmonizing	100%
Gatekeeping	99%
Encouraging	88%
Compromising	99%
Standard Setting	94%

Gender

A sequence of ten logistic regression analyses, one for each function, was used to examine whether male or female students were more likely to be observed displaying a given function at least once across the total observational period. Logistic regression requires that a specific group be designated as the standard to which the other groups will be compared. Since more engineering students are male, the male gender was designated as the standard to which female students would be compared. Three functions were found to be significantly different: Initiating ($p = 0.014$), Information Seeking ($p = 0.042$) and Standard Setting ($p = 0.033$).

Based on an odds ratio of 2.24, more than twice as many female students were witnessed Initiating across the total observational period than were male students ($p = 0.014$). Although women consistently displayed this function within each of the three time periods more than did men, these differences were not found to be significant. In other words, it was the accumulation of differences between males and females across the total observational period that accounted for the identified difference.

A significant odds ratio of 2.00 was also found for Information Seeking ($p = 0.046$) across the total observational period. In other words, twice as many female students were witnessed Information Seeking than were male students. When the analysis was broken down into the three time periods, only one significant difference was found and this difference occurred in the final time period. During the last four weeks of the course, almost three times as many women were (an odds ratio of 2.96, $p = 0.033$) witnessed Information Seeking than were men.

Women were also twice as likely to be witnessed Standard Setting (an odds ratio of 2.67, $p = 0.034$) across the total time period than were men. Within time periods, only one significant difference was found.

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During the first four weeks of the course, female students were witnessed Standard Setting almost six times more than male students, with an odds ratio of 5.81 ($p = 0.010$).

Group Composition

As was discussed earlier, logistic regression requires that a specific group be designated as the standard to which the other groups will be compared. Since there are more male engineering students, male dominated teams are more likely to occur within engineering. Given this, male dominated teams were designated as the standard to which the other team compositions would be compared. A sequence of ten logistic regression analyses, one for each function, was used to compare the functions that were displayed by individuals in female dominated and mixed gender teams to that of male dominated teams. Five functions were found to be significantly different either across the total observational period or within a given time period. These were: Initiating ($p = 0.032$), Information Seeking ($p = 0.002$), Clarifying ($p = 0.047$), Encouraging ($p = 0.002$) and Standard Setting ($p = 0.002$). Three of the differences (Initiating, Clarifying, Standard Setting) were attributable to a difference between female dominated teams and male dominated teams, and two of these differences (Information Seeking, Encouraging) are attributable to a difference between mixed gender teams and male dominated teams.

Across the total observational period a significant odds ratio of 2.72 ($p = 0.012$) was found for the function of Initiating for individuals who were in female dominated teams as compared to those that were in male dominated teams. In other words, more than twice as many individuals in female dominated teams were witnessed Initiating than were members of male dominated teams. When this analysis was broken down by time periods, no significant differences were found. This result is not surprising, given the earlier finding that more females displayed the function of Initiating than did males and that there are more female students on female dominated teams than there are on male dominated teams.

A significant odds ratio of 5.40 ($p = 0.001$) was found for individuals in female dominated teams with respect to Standard Setting as compared to male dominated teams across the total observational period. This suggests that more than five times as many individuals in female dominated teams were witnessed Standard Setting than were individuals in male dominated teams across the total observational period. Examination within time periods suggests that more than four times as many individuals in female dominated teams were witnessed Standard Setting during the first time period than were individuals in male dominated teams (an odds ratio of 4.18, $p = 0.019$). This result is consistent with the earlier finding that more females were witnessed Standard Setting in the first time period than were males. Given that there are more women in female dominated teams, it is reasonable to anticipate that individuals on these teams (females in particular) would be more likely to display this function.

No significant difference was found across the total observational period between individuals that were in female dominated teams and those that were in male dominated teams with respect to Clarifying. However, when this analysis was completed within time periods, there was a significant difference in the second time period (odds ratio of .30, $p = 0.024$). Fewer individuals in female dominated teams were witnessed Clarifying during the second time period than were individuals in male dominated teams. Another manner in which to state this result is that three times as many individuals in male dominated teams were witnessed Clarifying than were individuals in female dominated teams during the second time period. Since a difference was not witnessed between genders with respect to Clarifying, this finding is probably attributable to different team dynamics within male and female dominated teams.

In the first time period, fewer individuals in mixed gender teams were witnessed Information Seeking than were individuals in male dominated teams, as is suggested by the odds ratio of .06 ($p = 0.008$). No significant difference was found across the total observational period. Across the total observational period, fewer individuals in mixed gender teams were witnessed Encouraging than were individuals in male dominated teams. This was indicated by a significant odds ratio of 0.08 ($p = 0.016$). However, no significant difference was found within time periods.

Conclusions

As discussed at the start of this article, efforts are currently underway to increase the number of women that are pursuing degrees in engineering (Blaisdell & Anderson-Rowland, 1997; More, Blaisdell, & Anderson-Rowland, 2000; Moskal, Lasich & Middleton, 2001; White, Blaisdell & Anderson-Rowland, 1999). If these efforts are successful, then the composition of engineering design teams will gradually shift from being male dominated to a more equal distribution of genders. Prior research (MacDonell-Laeser et al., 2001; Moskal, Knecht & Lasich, 2002) has already started to predict the type of changes that are likely to take place as more women participate in the engineering design team process. This paper represents an extension of these efforts.

Several findings presented in this paper are consistent with those that were found in MacDonell-Laeser et al. (2001), who used a different set of statistical methods to examine the same set of data. For example, in the MacDonell-Laeser et al. analysis, the frequency with which Clarifying was witnessed in male dominated teams was greater than that which was witnessed in female dominated teams. This was consistent with the current finding that individuals in the male dominated teams were more likely to be witnessed Clarifying than were members of female dominated teams during the second time period. MacDonell-Laeser et al. (2001) also found that there was no difference between males and females in the following functions: Information Giving, Clarifying, Summarizing, Harmonizing, Gatekeeping, Encouraging, and Compromising. This was also true in the current study. Another commonality between

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the two studies was that no difference was found between male dominated, female dominated and mixed gender teams with respect to the following: Information Giving, Summarizing, Harmonizing, Gatekeeping, and Compromising.

The current study extends this prior work to the identification of when individuals in male dominated teams were more likely to be witnessed Clarifying than were members in female dominated teams. More than three times as many members of male dominated teams than members of female dominated teams were witnessed Clarifying during the middle three weeks of the course. No significant difference was found with respect to this function in the first four weeks and the last four weeks of the semester.

Other results presented here appear to contradict the findings of MacDonell-Laeser et al. (2001). Closer inspection of these results, however, suggests that this is not the case. MacDonell-Laeser et al. reported that, based on average proportions, there was no significant difference between the functions displayed by male and female students in engineering design teams. The current study found that more women than men were witnessed Initiating, Information Seeking and Standard Setting across the total observational period. The unit of measure used in each analysis explains these different findings.

MacDonell-Laeser et al's study was based on average proportions. This measured the proportion of times that a given individual was witnessed displaying a given function. The current study is based on whether a given individual was witnessed displaying the function across the entire period of interest. This does not account for the frequency with which a given individual displayed the function within that time period. In other words, the current investigation suggests that more women displayed the behaviors of Initiating, Information Seeking and Standard Setting than did men. However, across the entire set of males and females, there was no difference in the proportion of times that the behavior was displayed. Jointly these findings indicate that although the range of males to display these functions was less than that of females, the males that did display these functions did so at a higher rate than did their female counterparts.

The current study further identifies when women were more likely to display the function of Information Seeking as compared to men. Almost three times as many women displayed the function of Information Seeking as compared to men during the final four weeks of the course. No significant differences were found in the first four weeks or the second three weeks of the course. Almost six times as many women were witnessed Standard Setting than were men during the first four weeks of the course. No significant differences were found with respect to Standard Setting in the remaining weeks.

The difference in the unit of measure can also be used to understand the variation between the findings of MacDonell-Laeser et al. and the current results with respect to group composition. For example, in MacDonell-Laeser et al. male dominated teams displayed a higher frequency of the Encouraging function than did female dominated teams. No differences were found with respect to Encouraging between male dominated and female dominated teams in the current analysis. This suggests that Encouraging occurred

more in male dominated teams, because specific individuals within these teams repeatedly displayed this function. MacDonell-Laeser et al also found no difference between the frequency of Encouraging that took place in male dominated and mixed gender teams. The current study determined that more members of the male dominated teams were witnessed Encouraging than in the mixed gender teams. In combination, these results suggest that although more members of the male dominated teams displayed the function of Encouraging than did members of the mixed gender teams, these individuals did so at a lower rate than did members of the mixed gender teams.

MacDonell-Laeser et al. (2001) also determined that male dominated teams displayed a higher proportion of Standard Setting than did mixed gender teams. No difference was found between male dominated and mixed gender teams with respect to Standard Setting in the current study. However, in the current study more members of female dominated teams were witnessed Standard Setting than were members of male dominated teams. In other words, although more members of female dominated teams displayed the function of Standard Setting, the members of male dominated teams that did display this function did so at a higher rate than members of female dominated or mixed gender teams.

For the functions of Initiating and Information Seeking, MacDonell-Laeser et al. did not find a significant difference between team compositions. In the current analysis, significant differences were identified. More members of female dominated teams were witnessed Initiating than in male dominated teams. More members of male dominated teams were witnessed Information Seeking during the first time period than in mixed teams. In each of these cases, although there was no difference in the proportion in which the function was witnessed within a group composition there was a difference in the number of individuals that displayed the given function.

The current investigation also examined the time periods in which individuals were more likely to display the given function. For example, the function of Initiating was consistently displayed more by members of female dominated teams than by male dominated teams across the entire observational period. This is consistent with the earlier finding that more women displayed the function of Initiating than did men. Individuals in female dominated teams were more than four times more likely to be witnessed Standard Setting during the first time period than were members of male dominate teams. This is also consistent with the earlier finding that women were more likely to be witnessed Standard Setting in the first time period than were men. With respect to Clarifying, although there was no overall difference between the members of female dominated and male dominated teams, there was a difference in the second time period. Individuals in female dominated teams were less likely to be witnessed Clarifying in the second time period than were members of male dominated teams.

Taken in combination, the two studies provide a more complete picture of how male and female engineering design students function as teams. The functions that are displayed by the team members

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appear to be dependent both upon the gender of the individual team member and the gender composition of the teams. More importantly, differences can be witnessed in both the rate at which a given function is displayed and with respect to which members of the teams are more likely to display the function across time.

As is the case with any study that is focused within a given institution, the findings presented above must be interpreted with caution. The Colorado School of Mines specializes in training students in science and engineering. When students enter CSM, they have already made the decision to enter a science or engineering career. Therefore, the students at CSM are different from other first and second year students. The uniqueness of this population prevents the generalization of these findings to the broader population of engineering students. Further research is needed to determine the extent to which these differences exist in other schools of engineering that have different populations.

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